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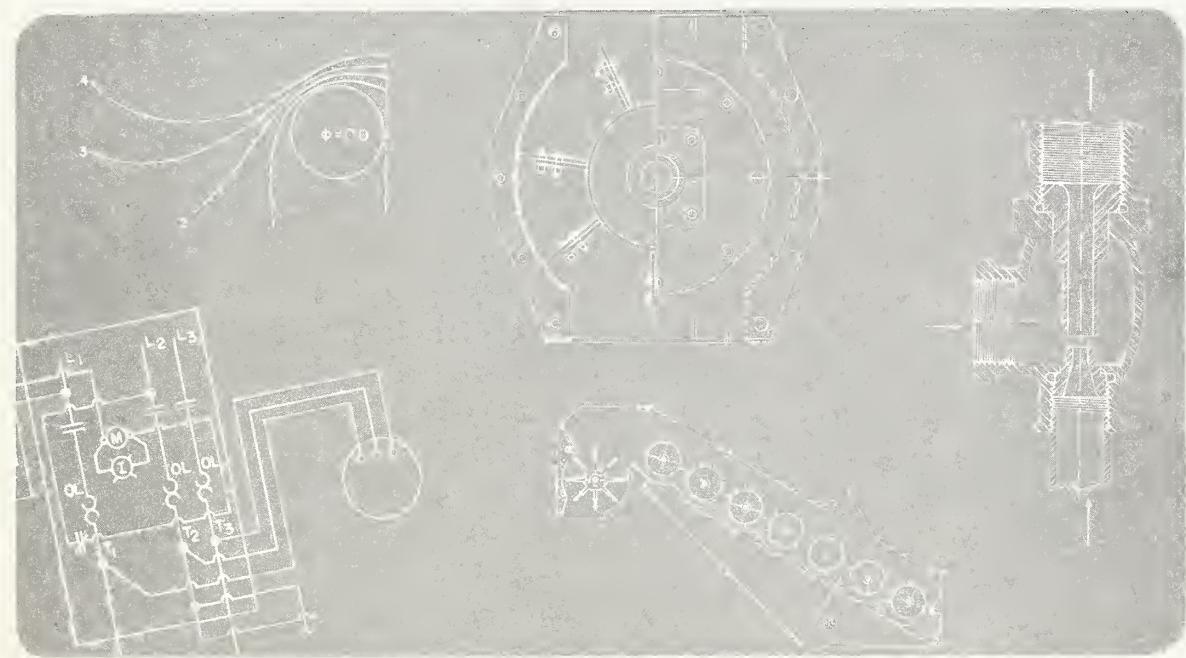
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Effects of Fiber Retrieval on the Quality and Value of Spindle-Picked Cotton

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Effects of Fiber Retrieval on The Quality and Value of Spindle-Picked Cotton

By Gino J. Mangialardi, Jr.,¹ and Joseph B. Cocke²

ABSTRACT

In ongoing research, experiments were conducted on a retriever developed for recovering spinnable fibers at cotton gins with lint cleaners to determine the potential monetary value of fibers returned to the bale and to evaluate the effects of the retrieved fibers on manufacturing performance and dust level at the mill and on yarn quality. The apparatus, which is a modified standard commercial lint cleaner reduced to a 13-inch width, recovered 9 to 18 pounds of spinnable fibers per bale from the foreign matter and fibers extracted by one, two, and three stages of saw-cylinder lint cleaning. It also blended these fibers back into the cotton stream through the lint duct between the gin stand and first lint cleaner concurrently with ginning. At 1979 cotton prices, the value of fibers recovered from two lint cleaners was about \$10 per bale. The apparatus allows the use of third-stage lint cleaning at gins to reduce foreign-matter content of cotton, since spinnable fibers formerly lost are recovered. Returning the recovered fibers to the bale had no significant effect on foreign-matter content, grade, staple length, or number of neps. Also, there was no significant change in fiber length or strength. During spinning tests, only one of the parameters tested, thick places per 1,000 yd, was significantly affected by the retrieving treatment. Retriever saw-cylinder sizes were established for gins handling 3 to 40 bales per hour. The retrieving tests placed emphasis on maintaining cotton quality and manufacturing performance. The retrieved fibers could also be salable as a separate product but would be of lesser value than if recycled back to the bale. Index terms: cotton-gin equipment, cotton-ginning losses, cotton quality, cotton value, lint cleaning, lint retriever.

INTRODUCTION

Seed-cotton-cleaning machines at gins use some form of reclaiming cylinder to recover cotton extracted with the foreign matter. This recovery oc-

curs early in the ginning operation, and the later processes insure blending the recovered cotton in the ginning stream. Lint cleaners are not equipped with lint reclaimers. The lint-cleaning process immediately precedes the baler, and later processes are not available to insure uniform blending of reclaimed fibers into the bale or to remove foreign matter that may be attached to the reclaimed fibers.

In July 1978, there were 2,726 gin batteries in the United States, and over 99 percent of those were using lint cleaners. Fourteen percent had one stage of cleaning, 65 percent had two stages,

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and 19 percent had three stages (U.S. Agricultural Marketing Service 1978). Research tests have shown that lint cleaners may extract as much as 70 pounds of material per bale, depending on the condition of the cotton and the number of lint cleaners used. In these tests, the amount extracted from typical Midsouth spindle-harvested cottons by one, two, and three stages of saw-cylinder lint cleaning averaged 20, 30, and 35 pounds per bale, respectively (Looney et al. 1963, Mangialardi 1972). The number of bales ginned annually in the United States ranged from 8.3 to 14.4 million during 1969-78 (U.S. Bureau of the Census 1979).

During the 1976-77 season, about 32 percent of the gins in the United States collected and sold fibrous material from cotton-gin waste. The number of gins collecting fibrous material or motes, mostly lint-cleaner wastes, ranged from 7 percent in Missouri to 95 percent in California. The total supply of motes in the United States was estimated at 93 million pounds. Ginnings received an average of 7.4 cents per pound for uncleaned motes and 12.8 cents per pound for cleaned motes, but the price varied widely by region and buyer (Ghetti and Glade 1978).

In 1964, researchers demonstrated a lint-retrieving system that delivered the fibrous portion of the lint-cleaner waste directly to the bale (Holder et al. 1967, Watson and Holder 1966). Although the system did not blend reclaimed material into the ginned lint, the recovery practice was shown to be feasible and worth pursuing further.

In early 1975, the U.S. Cotton Ginning Laboratory, Stoneville, Miss., initiated a project to retrieve 50 percent or more of the fibers extracted by lint cleaners and return them to the lint stream ahead of the lint cleaners with no interruption in the cotton flow. It was intended in this development that only spinnable fibers be retrieved and blended into the cotton stream. The experiments proved the lint-retrieval system to be operational, but its practicality needed further evaluation (Mangialardi 1977).

Further experiments with the system showed that about 13 pounds of usable fiber may be retrieved from lint extracted during two stages of saw-cylinder lint cleaning and returned to the bale. Although the retrieved lint had no significant effects on the foreign-matter content, grade classification, staple length, or nep count of the packaged cotton, an increase in ends down during

ring spinning indicated the need for further quality tests (Mangialardi and Cocke 1979a, 1979b).

This report presents results from completed laboratory retriever-system tests. Cottons for the experiments were ginned in 1977 at the U.S. Cotton Ginning Laboratory, and the test bales were processed through spinning in 1979 at the Cotton Quality Research Station, Clemson, S.C. The overall objective was to determine, from a quality standpoint, the amount of lint that it is practical to recover and to establish guidelines for properly deploying the lint retriever for use with one, two, and three stages of saw-cylinder lint cleaning.

Specific objectives of the experiments were (1) to determine the potential monetary value of fibers recovered and returned to the bale, (2) to evaluate the effect of blending retrieved fibers into bales on manufacturing performance at the mill and on yarn quality, and (3) to determine if the foreign-matter content of the bale and the dust level in the cardroom can be reduced by multiple stages of saw-cylinder lint cleaning with fiber retrieval without significantly reducing the

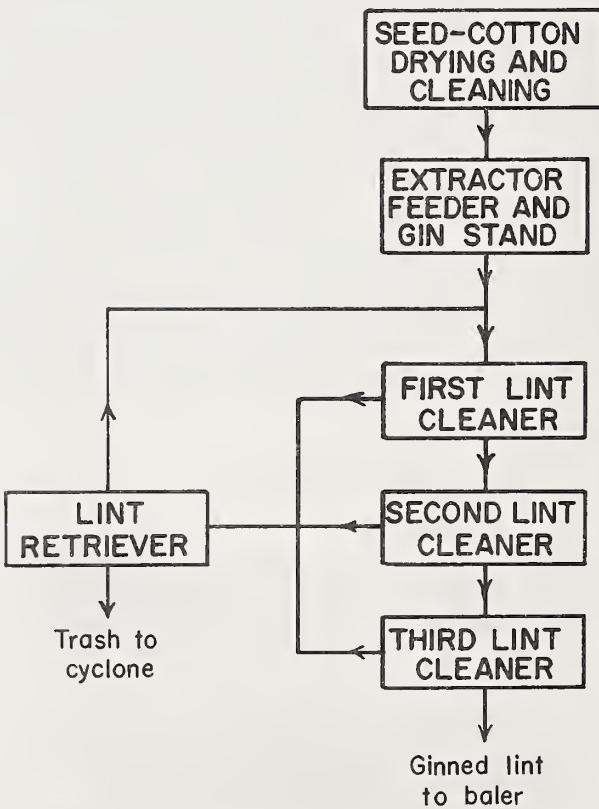


FIGURE 1.—Flow chart showing the lint-retriever recycling system.

market value of the bale. The foreign-matter content and cash value of the bales ginned with three stages of saw-cylinder lint cleaning, where retrieved lint was returned and uniformly distributed within the bale, were compared with those of bales ginned with two stages of cleaning without retrieving.

EQUIPMENT

The 1977 experiments were conducted in the U.S. Cotton Ginning Laboratory's commercial-size gin plant. The seed-cotton drying and cleaning sequence consisted of a 24-shelf tower drier, 6-cylinder cleaner, stick machine, 24-shelf tower drier, 6-cylinder cleaner, extractor feeder, and gin stand. Three saw-cylinder lint cleaners were available for use, and the lint-retrieving apparatus was installed to complete the machinery sequence (fig. 1). The lint retriever is a standard commercial lint cleaner that was reduced to a 13-inch width.

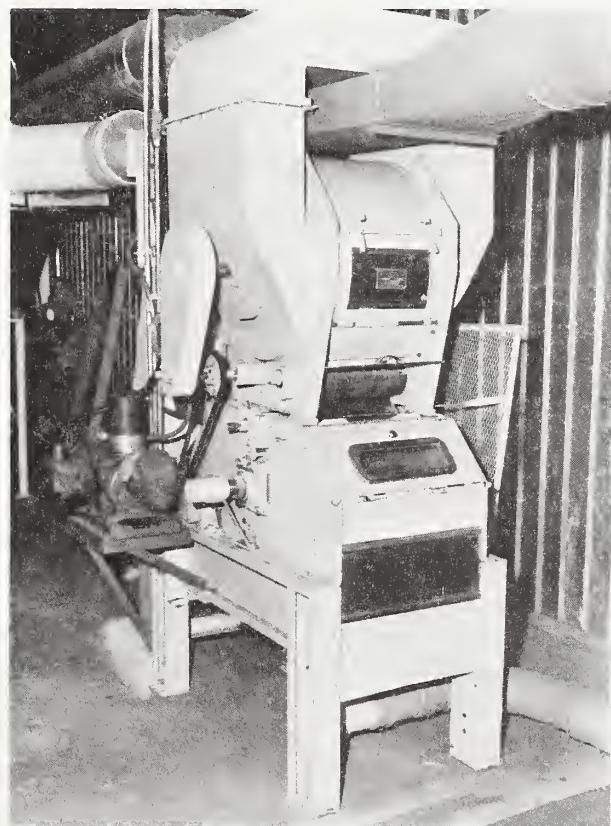


FIGURE 2.—Lint-retrieving unit for recovering fibers from lint-cleaner ejecta concurrently with ginning.

Centrifugal fans provide an air wash on each lint cleaner to overcome the air static pressures involved in conveying the ejecta from lint cleaner to retriever. The material can be collected by a condenser and sampled for analysis or it can be delivered to the retrieving unit, where most of the fibers are separated from the particulate (fig. 2).

Operation of the lint retriever begins where the lint-cleaner ejecta is collected on a condenser drum and formed into a batt, which is then fed through a set of compression rollers before it passes between a close-fitted feed roller and bar into the retriever saws. Five grid bars are used around the periphery of the saw cylinder. A 1.5 horsepower variable-speed motor with electric speed controller powers the condenser drum and drawing rolls and permits adjusting to a range of combing ratios. A combing ratio of 110 : 1 was used in the experiments. A 7.5-horsepower motor drives the 12.5-inch-diameter saw drum at 1,140 revolutions per minute. The drum surface is groove-wound with wire at a rate of 8 turns per inch and provides a tooth density of 48 teeth per square inch of drum surface.

The retrieved lint is collected at a condenser unit for evaluation (fig. 3) or is returned concurrently with ginning to the lint stream in the rectangular duct between the gin stand and the first

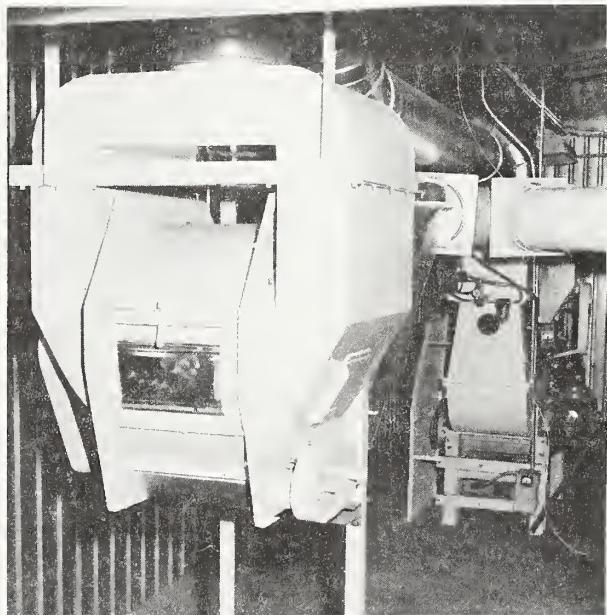


FIGURE 3.—Condenser unit for collecting retrieved lint for evaluation.



FIGURE 4.—Large rectangular duct to which retrieved lint returns through overhead duct to lint stream.

lint cleaner (fig. 4). Introduction of the lint at this point provides additional cleaning of the retrieved lint and allows the cleaners to blend it uniformly into the normal ginning stream (recycling). The waste ejected by the lint retriever is conveyed pneumatically to a cyclone collector for disposal.

PROCEDURES

Seed cotton used in the tests was grown and machine-harvested by the Delta Branch Experiment Station, Mississippi Agricultural and Forestry Experiment Station, Stoneville, Miss. Harvesting was done October 5–13, 1977, and the cotton was ginned October 7–November 11, 1977. Tests were performed in three replications and, in each replication, a homogeneous unit of six test lots received a different lint-cleaner and retrieving treatment. The six treatments were (1) one lint cleaner, (2) one lint cleaner with recycling, (3) two lint cleaners, (4) two lint cleaners with recycling, (5) three lint cleaners, and (6) three lint cleaners with recycling. Because of machinery-arrangement and air-balance problems, the treatment involving one lint cleaner with recycling was not tested on replication one. The problems were corrected for replications two and three. Thus, 17 bales, instead of the planned 18, were processed in the experiments. 'DES 56' was the variety used for replications one and three, and 'Stoneville 213' was used for replication two. The size of each test lot was one bale (about 1,375 pounds of seed cotton).

The three lint cleaners used in the experiments were operated according to the manufacturer's recommendations for commercial cotton-ginning plants. An electronic moisture meter served as an aid in adjusting the driers to control the moisture content of fiber at ginning. Ginning rate was controlled at about 4.5 bales per hour per gin stand.

For all lint-cleaner treatments where recycling was not used, material extracted from the bales by the lint cleaners was divided by the retriever unit into recovered-fibrous and rejected-trash portions. Analyses of these materials aided in ascertaining the amounts of lint recovered from the test bales and the percentage of fibers lost during the recycling process.

Three samples were taken from each of the test bales, according to a time schedule during ginning, for each factor to be studied. Seed-cotton samples were obtained for determining incoming seed-cotton moisture and foreign-matter content, and lint samples were collected for fiber tests and for determining lint moisture level during ginning and lint cleaning, foreign-matter content, and classer's grade and staple length. (American Society for Testing and Materials 1978a, 1978b). The packaged bales, material removed by the lint cleaners, and fibers collected by the retriever were weighed and analyzed with conventional methods. The weights of the packaged bales and collected material were adjusted to 512 pounds of lint before lint cleaning. The classification samples were graded by the U.S. Agricultural Marketing Service at Greenwood, Miss., and the fiber tests were conducted at Agricultural Research Service's Cotton Quality Research Station at Clemson, S.C. The fiber tests included nep counts and length measurements determined by the digital fibrograph method.

Cotton values for the experimental bales were determined from grade, staple length, micronaire reading, and net bale weight and were based on average spot cotton prices during August 1979–April 1980 at the nine locations designated as spot markets. The average price used for Strict Low Middling grade and a staple length of 34 thirty-seconds of an inch was 69.78 cents per pound (U.S. Agricultural Marketing Service 1980).

The 17 test bales were shipped to Clemson for processing through the Cotton Pilot Spinning Plant, where additional cotton quality tests were conducted, cardroom dust levels were monitored, and manufacturing performance and yarn quality

Table 1.—Moisture and foreign-matter contents of wagon samples, moisture contents of lint cotton, ginning rates, and retriever loads¹

Measurement	Machinery treatment					
	1 lint cleaner		2 lint cleaners		3 lint cleaners	
	Without recycling	With recycling	Without recycling	With recycling	Without recycling	With recycling
Wagon seed cotton:						
Moisture content	pct	13.0ab	11.6b	14.5bc	15.1c	12.6ab
Foreign-matter content	pct	7.5ab	7.2a	7.5ab	7.8b	6.9a
Lint moisture content	pct	5.5ab	5.6ab	6.6a	6.3a	5.0b
Ginning rate	bales/h	4.51	4.37	4.86	4.62	4.19
Retriever loads:						
Feed rate	lb/ft saw cyl/h . . . . .	.84	88	145	138	143
Batt density	lb/ft ²	0.041	0.043	0.072	0.068	0.071
						0.073

¹Data represent the average from 3 replications. Means in a row followed by different letters are significantly different at the 5-pct level.

were determined from ring- and open-end spinning tests.

Ring-spinning produced 30 Ne(19.7 tex)³ yarn. A hank roving of 1.00 was used with a roving twist multiplier of 1.30. Spinning break draft was 1.38; spindle-cradle setting, 0.157 inch; front-roller speed, 166 revolutions per minute; spindle speed, 10,500 revolutions per minute; and twist multiplier, 3.68. Spindle-hours tested per bale averaged 5,502.

Yarn of size 12 Ne(49.2 tex) was spun by the open-end spinning procedure from sliver weighing 55 grains per yard. A wire beater, a standard rotor (46,000 revolutions per minute), and a yarn twist multiplier of 5.00 were used.

A randomized complete-block experimental design was used with a factorial arrangement of treatments. Data were disproportionate and were analyzed with least squares procedures. The linear model used in the analyses included the random effects of replication, the fixed effects of lint cleaning, retrieval and lint cleaning by retrieval interaction, and the effects of random residual error. Tests of hypotheses concerning fixed effects were done via *t*-tests subsequent to *F*-tests in the analysis of variance (Steel and Torrie 1960).

RESULTS AND DISCUSSION

PREPROCESSING COTTON

Seed-cotton moisture and foreign-matter contents

Initial seed-cotton moisture content (table 1) averaged 13.4 percent for the three replications. Fractionation tests gave an average initial seed-cotton foreign-matter content of 7.3 percent. Differences in moisture content were significant at the 5-percent level among lint cleaners but were not significant between retrieving treatments in the same lint-cleaner category. Differences in the fractionation data were not statistically significant among lint-cleaning levels or between retrieving treatments.

Lint moisture contents

Lint sampled after ginning but before lint-cleaning showed that the moisture level for the six experimental treatments averaged 5.7 percent. Differences in lint moisture content among the lint-cleaning stages were significant at the 5-percent level, but data for the two retrieving setups were not significantly different.

³Ne, symbol of the indirect system of arriving at the yarn number. It denotes length per unit mass or the number of hanks (840 yards) required to weigh 1 pound; thus, the larger the Ne number, the smaller the yarn size.

Table 2.—Amounts of lint-cleaner ejecta, fibrous portion and trash, collected and returned to ginning stream; lint retrieved; and retrieved fibrous material lost to recycling¹

Measurement	Machinery treatment						
	1 lint cleaner		2 lint cleaners		3 lint cleaners		
	Without recycling	With recycling	Without recycling	With recycling	Without recycling	With recycling	Average
Fibrous portion retrieved	lb/bale	9.3a	10.9ab	18.6bc	14.4abc	20.7bc	18.1abc
	lb/bale	11.1	11.4	13.6	17.8	15.7	18.3
Trash rejected	lb/bale	.....	.....	.....	.....	.....	.....
Total ejecta collected	lb/bale	20.4	22.3	32.2	32.2	36.4	36.4
Ejecta material retrieved	pct	44.3	46.3	57.4	45.2	56.9	45.0
Amount of actual lint retrieved	lb/bale	7.8	.....	14.6	.....	15.9	.....
Retrieved fibrous material lost to recycling	pct	.....	2-10	.....	20.8	.....	21.0
							15.4

¹Data represent the average from 3 replications and are based on 512 lb of lint per bale before lint cleaning. Means in a row followed by different letters are significantly different at the 5-pct level.

²The value is lower than zero because of the wide range in data.

Table 3.—Sizes of saw cylinder required for lint retriever to handle materials extracted by 1, 2, and 3 stages of lint cleaning at ginning rates ranging from 3 to 40 bales per hour¹

Ginning rate (bales/h)	Saw-cylinder length (inches) required for—		
	1 lint cleaner	2 lint cleaners	3 lint cleaners
3	6	9	10
4	8	12	14
5	10	15	17
6	12	18	21
8	16	25	28
10	20	31	35
12	24	37	42
15	30	46	52
18	36	55	62
21	42	65	73
24	48	74	83
27	54	83	93
30	60	92	104
35	71	108	121
40	81	123	138

¹These data are based on 21, 32, and 36 lb of ejecta extracted per bale when using 1, 2, and 3 stages of lint cleaning, respectively. Retriever handles 125 lb of ejecta per foot of saw-cylinder length.

LINT-CLEANER EJECTA

Total ejecta collected from the one, two, and three lint-cleaner treatments averaged about 21, 32, and 36 pounds per bale for the three replications (table 2). With the retriever in operation, about 49 percent of the ejecta extracted by the lint-cleaning systems was recovered and recycled to the cotton stream. The retrieved fibrous portion averaged about 10, 16, and 19 pounds per bale for the one, two, and three lint-cleaner treatments.

About 15 percent of the fibrous material recovered by the retriever was lost to recycling. This loss was attributed to further cleaning of the retrieved material by the lint cleaners.

RETRIEVER OPERATION

When processing cotton through one, two, and three stages of lint cleaning, materials extracted by the cleaners were fed to the retrieving apparatus at average rates of about 86, 142, and 146 pounds per foot of retriever saw-cylinder length

per hour (table 1). For the combing ratio used (110 : 1), these feed rates provided an average batt density of 0.041 to 0.073 pound per square foot at the feed plate of the retriever.

No mechanical problems were encountered in feeding the batts through the retrieving apparatus. At batt densities of 0.035 pound per square foot at the feed plate, the batt was thin and had gaps in it. A solid continuous batt was obtained at about 0.05 pound per square foot. (For long-term trouble-free operation, batts with densities above 0.07 pound per square foot should not be used.) The surface of the retrieving saw cylinder remained clean during processing, and no trash clogged the saw teeth.

Retriever saw-cylinder sizes were established to handle material extracted by one, two, and three stages of lint cleaning at ginning rates ranging from 3 to 40 bales per hour (table 3). These would be the sizes required at commercial gin plants processing spindle-picked cotton. The sizes were based on a feed rate of 125 pounds of ejecta per foot of retriever saw-cylinder length per hour, a combing ratio of 110 : 1, and a batt density of 0.06 pound per square foot at the feed plate. Tip speed of the retriever saws was 3,740 feet per minute.

As an example of a typical retrieving system operating under these conditions, a plant with a ginning rate of 21 bales per hour and having two stages of lint cleaning would require a retriever saw-cylinder length of 65 inches. One standard 66-inch lint cleaner could be modified to process the ejecta at this gin plant. For this plant, the capital equipment and operating costs for the lint recovery system are estimated at about 32 cents per bale (Looney et al. 1963, U.S. Bureau of Labor Statistics 1980).

GINNED LINT

Foreign-matter contents and cleaning efficiency

Foreign-matter content of the ginned lint, as determined by the Shirley analyzer method, indicated that cottons used in replication 2 contained greater amounts of foreign matter than the cottons used in replications 1 and 3 (table 4). Lint foreign-matter content for the study averaged 7.88 percent before lint cleaning and ranged from 3.36 to 4.79 percent at the baler for the six

Table 4.—Foreign-matter contents in ginned and retrieved lint and lint-cleaning efficiency¹

Measurement	Machinery treatment					
	1 lint cleaner		2 lint cleaners		3 lint cleaners	
	Without recycling	With recycling	Without recycling	With recycling	Without recycling	With recycling
Foreign-matter content:						
Before lint cleaning	pct	7.28	7.53	8.82	8.44	7.53
After lint cleaning	pct	4.73ab	4.77ab	4.79a	4.60ab	3.36b
Retrieved lint	lb/bale	16.59	.....	22.96	.....	20.85
Lint-cleaning efficiency	pct	35.1a	36.7ab	47.1abc	44.8abc	53.6c
						49.8bc
					
						7.68
						7.88
						3.71ab
						20.13
					

¹Data represent the average from 3 replications. Means in a row followed by different letters are significantly different at the 5-pct level.

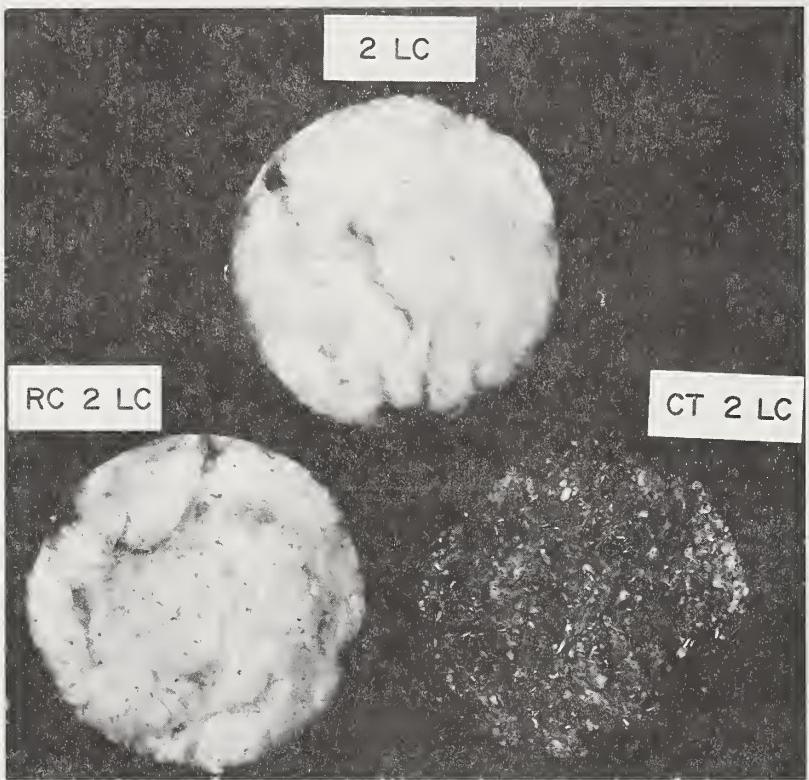


FIGURE 5.—Lint ginned with two lint cleaners (2LC) and the extracted ejecta, which was divided into a retrieved cotton portion (RC 2LC) and rejected (cyclone) trash (CT 2LC) by the retrieving system.

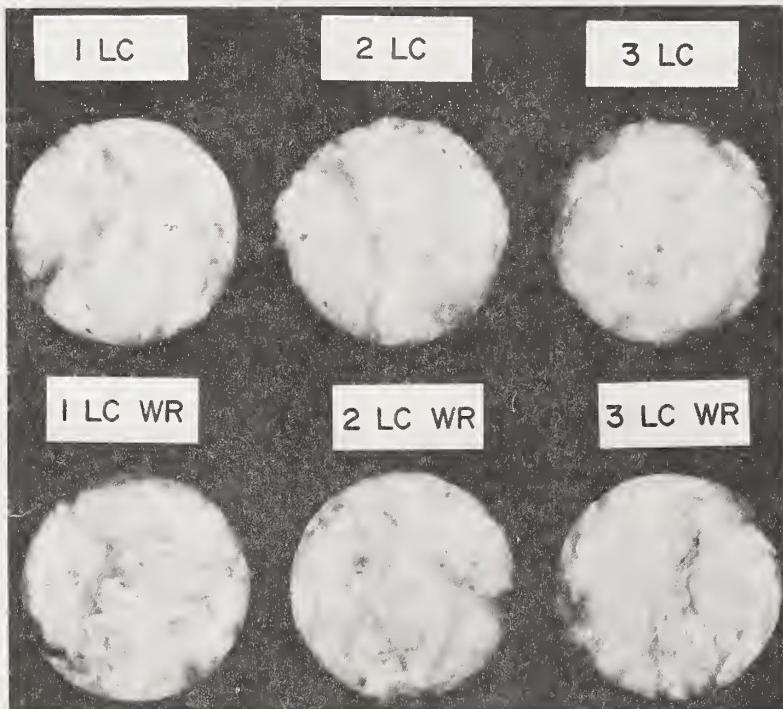


FIGURE 6.—Effects of one, two, and three stages of lint cleaning (LC) on foreign matter remaining in cotton. Upper samples were ginned without retrieving, and the lower samples were processed with retrieved lint (WR) recycled to the bale.

lint-cleaning and retrieving treatments. Recycling slightly increased the foreign-matter content of the lint for the one and three lint-cleaner treatments but produced a decrease in the foreign matter for the two lint-cleaner treatment. Lint foreign-matter content for the three lint cleaners with recycling was lower than that for the one or two lint-cleaner treatments where recycling was not used. The differences among lint cleaners were statistically significant, but the differences between the recycling treatments in the same lint-cleaner category were not significant. Foreign-matter content of lint retrieved but not recycled to the bale averaged about 20 percent for the experiments.

Typical samples showing the ability of the retriever to recover fibers from the lint-cleaner ejecta are shown in figure 5. The upper sample was collected at the baler after two stages of lint cleaning, and the lower samples show the ejecta from two cleaners divided into a retrieved-fibrous portion (left) and rejected (cyclone) trash portion (right).

Figure 6 depicts the effects of one, two, and three stages of lint cleaning on foreign matter remaining in cotton. The upper samples shown were ginned without recycling, and the lower samples were processed with retrieved lint recycled to the cotton stream.

Lint-cleaning efficiency, determined from foreign-matter contents, averaged about 36, 46, and 52 percent when one, two, and three stages of lint cleaning were used (table 4). Again, differences in cleaning efficiency among the lint cleaners were statistically significant, but the differences between the retrieving treatments were not significant.

Classer's grades and staple lengths

Grade designations for the cottons used in the experiments averaged Low Middling Light Spotted before lint cleaning (table 5) and improved with lint cleaning. Differences in grade index were not significant between one and two lint cleaners, but the differences between one and three, and two and three lint cleaners were significant. Based on the classer's grade and other tests, the cotton used for replication 2 was inferior in quality to that processed in replications 1 and 3. Cottons ginned in replication 2 were generally of a lower white grade or contained more off-color cotton.

Grade indexes for the bales containing retrieved cotton were slightly lower than for the bales processed without recycling when using one

Table 5.—Classer's grade and staple-length designations, bale weights, and lint value of bales ginned in cotton retrieving experiments¹

Measurement	Machinery treatment					
	1 lint cleaner		2 lint cleaners		3 lint cleaners	
	Without recycling	With recycling	Without recycling	With recycling	Without recycling	With recycling
Grade index:						
Before lint cleaning	82.1	80.0	78.3	75.0	78.4	81.4
After lint cleaning	88.1a	87.6a	88.1a	88.1a	94.3b	94.3b
Grade designation:						
Before lint cleaning	LMLtSp	LMLtSp	LMLtSp	LMSpLt	SGO	SGO+ SLM
After lint cleaning	SLMLtSp	SLMLtSp	SLMLtSp	SLM+	SLM	SLM
Staple length:						
Before lint cleaning	32d inch	34.6	34.3	34.3	34.7	34.3
After lint cleaning	32d inch	34.8	34.7	34.9	34.8	34.4
Bale weight	lb	492a	501a	480b	494a	476b
Value per bale:³						
Before lint cleaning	\$324.62	\$314.60	\$308.39	\$311.11	\$326.42	\$333.02
After lint cleaning	\$325.84ab	\$335.82b	\$317.91a	\$332.30ab	\$330.16ab	342.93b

¹Data represent the average from 3 replications. Means in a row followed by different letters are significantly different at the 5-pct level.

²Grades averaged LMLtSp, GO+, and LM for replications 1, 2, and 3, respectively.

³Bale values are based on bale weight and spot market price quotations.

lint cleaner, and indexes were the same, with and without recycling, for the bales subjected to two and three stages of lint cleaning. When comparing cottons processed with recycling against those where recycling was not used, differences in grade index were small and not significant. Cotton ginned with three lint cleaners, without and with recycling, produced average grades of Strict Low Middling White compared to grades of Strict Low Middling Light Spotted for lint ginned with one and two lint cleaners without recycling.

Classer's staple length increased slightly with lint cleaning. When one and two lint cleaners were used, recycling the recovered lint slightly decreased the staple length of the bale. A slight increase in length occurred when recycling was used with three lint cleaners. Overall, no significant change in staple length was attributed to the retrieving and recycling machinery setups.

Fiber properties and nep counts

Fiber testing of samples taken from ginned lint indicated the cotton to be of normal maturity. Micronaire readings for replications 1, 2, and 3 were 4.6, 4.3, and 4.5, respectively. Measurements by the digital fibrograph method showed a slight decrease in fiber length with lint cleaning

(table 6). Fiber length for replication 2 was shorter than that for replications 1 and 3. Fiber lengths in the lots subjected to the recycling treatments were slightly shorter than those in lots that were not recycled at the one and two lint-cleaner levels but were slightly longer at the three lint-cleaner level. None of the significant differences in the measurements were attributed to recycling the retrieved lint during the lint-cleaning process.

The average 2.5-percent span length, 50-percent span length, and length uniformity ratio for all after-lint-cleaning treatments combined were 1.14 inches, 0.52 inch, and 45.4 percent, respectively. Corresponding measurements for lint retrieved but not recycled were 1.09 inches, 0.46 inch, and 42.4 percent (table 7).

The number of neps per 100 square inches of web after lint cleaning averaged about 17, 21, and 27 for the treatments using one, two, and three stages of lint cleaning, respectively (table 6). Three lint cleaners without recycling produced a significantly higher nep count than one lint cleaner without recycling. The recycling treatments produced a slightly higher average nep count when used with one lint cleaner but lower nep counts when used with two or three lint cleaners. Overall, nep count differences attributed to recycling the retrieved lint back into the main ginning stream were not significant. Lint retrieved from the lint-cleaner ejecta but not

Table 6.—Digital fibrograph values and nep counts for lint ginned in retrieving experiments¹

Measurement	Machinery treatment					
	1 lint cleaner		2 lint cleaners		3 lint cleaners	
	Without recycling	With recycling	Without recycling	With recycling	Without recycling	With recycling
2.5-pct span length:						
Before lint cleaning	inches ...	1.155	1.145	1.162	1.160	1.152
After lint cleaning	do ...	1.140	1.125	1.147	1.140	1.128
50-pct span length:						
Before lint cleaning	inch ...	0.541	0.532	0.547	0.541	0.543
After lint cleaning	do ...	0.522	0.509	0.521	0.520	0.505
Uniformity ratio:						
Before lint cleaning	pct ...	46.9	46.5	47.1	46.7	47.1
After lint cleaning	pct ...	45.8	45.2	45.4	45.7	44.8
Neps:						
Before lint cleaning	No./100 inch ² of web ...	14.0	15.0	11.7	11.3	11.1
After lint cleaning	No./100 inch ² of web ...	16.4a	18.3a	22.1abc	20.2ab	28.9c
¹ Data represent the average from 3 replications. Means in a row followed by different letters are significantly different at the 5-pct level.						

recycled contained about 35 neps per 100 square inches of web.

Bale weights and values

Net bale weights increased from 492 to 501, 480 to 494, and 476 to 494 pounds for the one, two, and three lint-cleaner treatments as a result of retrieving and recycling (table 5). These increases in net bale weight were not significant statistically for one lint cleaner but were significant when two and three lint-cleaning stages were used. Cotton ginned with three lint cleaners plus retrieving and recycling produced bale weights that were as high or higher than those of cotton ginned with one or two lint cleaners without lint retrieving.

All lint-cleaning treatments increased the value of the cotton bale when compared with its value before lint cleaning (table 5). At 1979 prices, average bale values for the treatments in which retrieved lint was recycled back into the ginning stream were \$9.98, \$14.39, and \$12.77 higher at the one, two, and three lint-cleaner levels than for the treatments in which no retriever was used. The bale-value increases averaged \$12.38 for all retriever treatments tested. Highest bale value was obtained on the machinery setup using three lint cleaners with recycling.

Based on the bale-value increases obtained in the study, the value of the recovered and recycled fibers would be about \$118 million at 1979 prices for an annual crop production in the United States of 8.8 million spindle-picked bales. If

Table 7.—Digital fibrograph values and nep counts for lint retrieved in cleaning experiments¹

Measurement	No. lint cleaners used		
	1	2	3
2.5-pct span length inches	1.100	1.097	1.073
50-pct span length inch	0.474	0.458	0.453
Uniformity ratio pct	43.1	41.8	42.2
Neps No./100 inch ² of web	35.1	35.6	34.2

¹Data represent the average from 3 replications. The lint was retrieved from lint-cleaner ejecta by the retriever but was not recycled back into the ginning stream.

Table 8.—Official classification of ginned lint sampled at Cotton Pilot Spinning Plant¹

Measurement	Machinery treatment					
	1 lint cleaner		2 lint cleaners		3 lint cleaners	
	Without recycling	With recycling	Without recycling	With recycling	Without recycling	With recycling
Color grade:						
Index	89.0a	87.0a	92.3ab	92.3ab	94.3bc	94.3bc
Designation	SLMLtSp	SLMLtSp	SLM	SLM	SLM	SLM
Leaf grade:						
Index	94.0a	94.0a	94.0a	94.0a	98.0b	98.0b
Designation	SLM	SLM	SLM	SLM	M	M
Preparation	Normal	Normal	Normal	Normal	Normal	Normal
Composite grade:						
Index	89.0a	87.0a	92.3ab	92.3ab	94.3b	94.3b
Designation	SLMLtSp	SLMLtSp	SLM	SLM	SLM	SLM
Staple length 32d inch	35	35	36	35	35	35

¹Data represent the average from 3 replications. Means in a row followed by different letters are significantly different at the 5-pct level.

Table 9.—Pressley strength and colorimeter values for ginned lint samples at Cotton Pilot Spinning Plant¹

Measurement	Machinery treatment						
	1 lint cleaner		2 lint cleaners		3 lint cleaners		
	Without recycling	With recycling	Without recycling	With recycling	Without recycling	With recycling	Average
Pressley strength, $\frac{1}{8}$ -inch gage g/tex	24.5	24.2	24.5	24.4	24.3	24.3	24.4
Colorimeter, ginned lint:							
Reflectance (R_d) pct	70.9	71.2	71.9	72.1	72.7	72.4	71.7
Yellowance (+b)	9.0	9.1	9.4	9.2	9.4	9.3	9.1
Grade designation SLM		SLM	SLM	SLM	SLM	SLM	SLM
Colorimeter, cleaned lint: ²							
Reflectance (R_d) pct	73.7	74.8	73.8	73.8	74.0	74.4	74.1
Yellowance (+b)	9.5	9.2	9.5	9.5	9.4	9.4	9.4
Grade designation M	M	M	M	M	M	M	M

¹Data represent the average from 3 replications. Average differences among the lint cleaners and retrieving treatments are not significant at the 5-pct. level for any of the measurements listed.

²Lint cleaned by passing it twice through the Shirley analyzer.

adapted for use with machine-stripped cotton, the value of the recovered fibers would be an additional \$71 million for the 5.3 million bales machine-stripped in 1979. For processing cotton of Strict Low Middling grade with two stages of lint cleaning, a practical value would be about \$10 per bale or up to \$113 million per year for the average 1969-78 annual production in the United States of 11.3 million bales (U.S. Economic Research Service 1980, U.S. Bureau of the Census 1979).

We demonstrated that three stages of saw-cylinder lint cleaning, with retrieved lint returned and uniformly distributed within the bale, produces cotton of lower foreign-matter content and higher cash value than two stages of cleaning without retrieving. For the conditions of the experiments, three lint cleaners with recycling produced a foreign-matter content of 3.71 percent and a bale value of \$342.93, compared to corresponding values of 4.79 percent and \$317.91 for the two lint cleaners without recycling. Just one lint cleaner with recycling produced a bale value of \$335.82.

Prespinning samples

Sampling of the bales at the Cotton Pilot Spinning Plant showed no significant differences in the official classification data when comparing bales lint-cleaned without and with retrieving (table 8). Color-grade designations for the six lint-cleaner treatments averaged Strict Low Middling Light Spotted and Strict Low Middling White, and staple lengths were 35 and 36 thirty-seconds of an inch. Leaf-grade indexes averaged 94 to 98 for the six treatments, and corresponding composite grade indexes averaged 87 to 94. All bales ginned were of normal preparation.

Tests again indicated the cotton to be of normal maturity (table 9). Strength of the ginned lint was not significantly changed by the retriever treatments. Pressley strength (1/8-inch gage) ranged from 24.2 to 24.5 grams per tex for the six setups tested.

Colorimeter tests showed no significant differences among the six lint-cleaning and retrieving treatments for reflectance (R_d), yellowness (+b), or grade designation (table 9) (U.S. Agricultural Marketing Service 1963). Colorimeter grade designations for each of the six treatments averaged Strict Low Middling for

Table 10.—Digital fibrograph lengths for ginned lint sampled at Cotton Pilot Spinning Plant¹

Measurement	Machinery treatment					
	1 lint cleaner		2 lint cleaners		3 lint cleaners	
	Without recycling	With recycling	Without recycling	With recycling	Without recycling	With recycling
2.5-pct span length inches	1.127	1.125	1.127	1.123	1.107	1.107
50-pct span length inch	0.480	0.470	0.480	0.473	0.467	0.470
Length uniformity ratio pct	42.7	42.0	42.7	42.3	42.0	42.0

¹Data represent the average from 3 replications. Average differences among the lint cleaners and retrieving treatments are not significant at the 5-pct level for any of the measurements listed.

Table 11.—Waste collected, nep counts, and cardroom dust levels at Cotton Pilot Spinning Plant¹

Measurement	Machinery treatment					
	1 lint cleaner		2 lint cleaners		3 lint cleaners	
	Without recycling	With recycling	Without recycling	With recycling	Without recycling	With recycling
Waste:						
Opening and picking pct	0.71a	0.77a	0.43bc	0.55ab	0.32c	0.33c
Card pct	2.59a	2.72a	2.38a	2.39a	1.85b	2.03b
Total pct	3.30a	3.49a	2.81b	2.94ab	2.17c	2.36c
Neps No./100 inch ² of web	9.3a	9.5a	9.7a	10.0ab	11.3ab	12.0b
Dust level:²						
Personal sampler mg/m ³	2.61a	2.44ab	2.52a	2.39ab	2.07b	2.10b
Vertical elutriator mg/m ³	1.99a	2.01ab	1.92ab	1.91ab	1.71b	1.71b

¹Data represent the average from 3 replications. Means in a row followed by different letters are significantly different at the 5-pct level.

²Carding rate was 40lb/h; 800 ft³/min of air supplied to card room.

ginned lint and Middling for lint that had been cleaned by passing it twice through the Shirley Analyzer.

Measurements by the digital fibrograph showed no significant differences in fiber length among the one, two, and three lint-cleaner setups or between the treatments where lint was cleaned with and without retrieving and recycling (table 10).

Cardroom waste, nep counts, and dust levels

Manufacturing wastes, extracted during processing for spinning, decreased significantly when the level of lint cleaning increased but were

not significantly affected by the retrieving and recycling treatment (table 11). Opening and picking waste and card waste ranged from 0.32 to 0.77 percent and 1.85 to 2.72 percent, respectively, for the six lint-cleaner treatments. Total wastes for all treatments averaged 3.32 percent for replication 2, compared to the lower values of 2.40 and 2.62 percent for replications 1 and 3.

Neps in the card web were not significantly affected by the retriever treatments. Neps per 100 square inches of card web ranged from 9 to 12 for the six lint-cleaning and recycling setups.

Dust levels in the cardroom, measured by both the personal sampler and vertical elutriator, decreased with lint cleaning, and the total decreases between processing cottons in one lint cleaner and three lint cleaners were significant.

Table 12.—Values for noncellulosic constituents and fiber properties of drawing sliver prepared for spinning¹

Measurement	Machinery treatment					
	1 lint cleaner		2 lint cleaners		3 lint cleaners	
	Without recycling	With recycling	Without recycling	With recycling	Without recycling	With recycling
Noncellulosic constituents:²						
Sugar content	pct	0.15	0.14	0.15	0.15	0.14
Wax content	pct	0.51	0.51	0.50	0.48	0.48
Alcohol extractables	pct	1.31	1.29	1.33	1.33	1.29
Micronaire reading		4.4	4.4	4.5	4.5	4.5
Pressley strength, $\frac{1}{8}$ inch gage	g/tex	23.7	23.3	23.7	23.9	22.8
Digital fibrograph:						
2.5-pct span length	inches	1.13	1.12	1.14	1.14	1.13
50-pct span length .....	.inch	0.52	0.50	0.52	0.52	0.52
Length uniformity ratio	pct	46.7	45.3	46.0	45.3	46.3

¹Data represent the average from 3 replications. Average differences among the lint cleaners and retrieving treatments are not significant at the 5-pct level for any of the measurements listed.

²There was no hydrocarbon contamination for any of the bales tested.

Differences in dust levels measured between the without- and with-recycling treatments were small and not significant. Dust measurements for the six treatments averaged 2.36 and 1.88 milligrams per cubic meter when measured by the personal sampler and vertical elutriator, respectively. Cardroom dust levels for cottons cleaned with three lint cleaners and recycling were lower than for cottons cleaned with one or two lint cleaners and no recycling.

Drawing sliver

Tests on drawing sliver indicated that there were no significant differences among the six lint-cleaning and retrieving treatments for the noncellulosic constituents of the cotton (table 12). Sugar content, wax content, and alcohol extractables averaged 0.14, 0.50, and 1.32 percent, respectively, for the study. There was no hydrocarbon oil contamination for any of the bales tested. Micronaire readings on the sliver averaged 4.46 for the six treatments, and average differences among the treatments were not significant. Pressley strength data for drawing sliver were not significantly affected by the treatment setups. The 1/8-inch-gage tests produced average figures ranging from 22.8 to 24.1 grams per tex for the lint-cleaner and retrieving machinery treatments.

There were no significant differences among the treatment setups in 2.5- and 50-percent span lengths. Fibers in the sliver were somewhat longer than those measured in ginned lint sampled from the bale at the Cotton Pilot Spinning Plant. Span lengths (2.5- and 50-percent) and length uniformity ratio averaged 1.13 inches, 0.52 inch, and 46 percent, respectively, for sliver and 1.12 inches, 0.47 inch, and 42 percent, respectively, for ginned lint before carding and drawing (table 10).

SPINNING PERFORMANCE AND YARN QUALITY

Ring-spun yarns

Ends down per 1,000 spindle-hours of ring spinning of 30 Ne(19.7 tex) yard ranged from 9 to 88 for the 16 bales for which data on ends down were obtained (table 13). Differences in ends down among the lint-cleaning and retrieving treatments were not significant. In the four without- and with-retrieving comparisons of replications 1 and 3, where ends down data were available, the lower number of ends down occurred with the retriever in the system; these bales averaged 16 and 12 neps per 1,000 spindle-hours for the without- and with-retrieving treatments, respectively. The number of ends

Table 13.—Values for properties of yarn produced by ring spinning¹

Measurement	Machinery treatment		
	1 lint cleaner	2 lint cleaners	3 lint cleaners
Without recycling	With recycling	Without recycling	With recycling
Ends down ²	No./1,000 spindle hours	30	40
Break factor	1,905a	1,818ab	1,855ab
Yarn appearance:			
Index	102a	99a	99ab
Grade	C+	C+	C+
Single strand (Uster):			
Strength	g	230	228
Elongation	pct.	5.6	5.4
Strength CV	pct.	11.5	11.7
Neps	No./1,000 yd.	1,219a	1,199a
Thick places	No./1,000 yd.	2,993a	3,068ab
Low places	No./1,000 yd.	4,763a	4,902ab
Irregularity CV ⁴	pct.	22.3a	22.4ab
		22.5ab	22.5ab

¹Data represent the average from 3 replications. Means in a row followed by different letters are significantly different at the 5-pct level.²Data for replications 1 and 3 averaged 16 and 12 ends down/1,000 spindle-hours for the without- and with-retrieving treatments, respectively.

For the 16 bales for which data were obtained, ends down/1,000 spindle-hours ranged from 9 to 88.

³Because of a tape punch malfunction, data from replication 1 were not collected.⁴CV, coefficient of variability.

Table 14.—Values for properties of yarn produced by open-end spinning¹

Measurement	Machinery treatment					
	1 lint cleaner		2 lint cleaners		3 lint cleaners	
	Without recycling	With recycling	Without recycling	With recycling	Without recycling	With recycling
Break factor	1,810	1,756	1,798	1,827	1,791	1,780
Yarn appearance:						
Index	117a	112ab	107bc	112ab	110bc	105c
Grade	B+	B	B	B	B	B
Single strand (Uster):						
Strength	g.....478	468	470	485	482	479
Elongation	pct.....5.7	5.4	5.5	5.7	5.7	5.7
Strength CV	pct.....12.7	11.0	11.2	12.1	11.5	11.0
Neps	No./1,000 yd	387ab	436b	310a	453b	386ab
Thick places	No./1,000 yd	322	250	248	296	264
Low Places	No./1,000 yd	1,538	1,524	1,368	1,626	1,490
Irregularity CV ²	pct	15.5ab	15.2ab	15.1b	15.6a	15.5ab

¹Data represent the average from 3 replications. Means in a row followed by different letters are significantly different at the 5-pct level.

²CV, coefficient of variability.

down per 1,000 spindle-hours averaged 25 and 38 for all of the without- and with-retrieving treatments; the difference was attributed mainly to the low grade of cotton processed in replication 2.

There was no significant change in skein break factor when the retriever was used. Appearance index of the yarn decreased slightly when lint cleaning was increased from one to three stages, but the differences in the index between cottons that were cleaned without and with the retriever within each treatment category were not significant. Yarn-appearance grade averaged C+ for cottons ginned with each of the six lint-cleaning and retrieving treatments.

Single-strand data (Uster) showed no significant change in strength or elongation resulting from lint cleaning or retrieving. Average skein strength ranged from 220 to 230 grams for the six lint-cleaning and retrieving treatments. Neps counted per 1,000 yards of yarn did not differ significantly between the lots cleaned without and with the retriever at the one, two, or three lint-cleaner levels. Also, there was no significant increase in imperfections with use of the retriever. Thick and low places per 1,000 yards increased about 3 percent when comparing treatments where the retriever was used with treatments where the retriever was not used. This small increase attributed to the retriever was not significant at any of the lint-cleaning levels. The slight increase in irregularity coefficient of variability with the retriever in use was not significant.

Open-end yarns

Skein break factor of the 12 Ne(49.2 tex) yarn spun by the open-end procedure did not change significantly with degree of lint cleaning or when the retriever recycled recovered fibers back to the cotton stream (table 14). Appearance indexes of the yarn differed only slightly among the six treatments, and differences were not significantly attributed to use of the retriever. Single-strand data (Uster) showed no significant change in strength and elongation with degree of lint cleaning or with use of the retriever. Strength was slightly higher when the recovered fibers were recycled at the two lint-cleaner level and slightly lower when recycled at the one or three lint-cleaner levels.

There were slight increases in the number of neps counted per 1,000 yards of yarn and in the irregularity coefficient of variability when the retrieving and recycling procedure was used with two lint cleaners, but the differences were not significant when this procedure was used with one or three lint cleaners. The number of imperfections (thick and low places) were not significantly affected by the lint-cleaning and retrieving treatments.

CONCLUSIONS

This study showed that the lint-cotton retriever may be used to reduce lint losses at gins. If used as in these experiments, no mechanical or cotton-flow problems should be encountered. About 1 foot of the length of the lint retriever would be required for each 10 feet of installed lint-cleaning machinery. The retriever would operate at a combing ratio of 110 : 1 and handle about 125 pounds of lint-cleaner ejecta per foot of retriever saw-cylinder length per hour.

We demonstrated that three stages of saw-cylinder lint cleaning, with retrieved lint returned and uniformly distributed within the bale, produces cotton of lower foreign-matter content and higher cash value than two stages of cleaning without retrieving. In these experiments, three lint cleaners with recycling produced a foreign-matter content of 3.71 percent and a bale value of \$342.93, compared to corresponding values of 4.79 percent and \$317.91 for two lint cleaners without recycling. The average amount of lint recovered ranged from 9 to 18 pounds per bale, and the data indicated that the amount recovered would increase with the use of additional lint cleaners. The retrieved lint had no significant effects on the foreign-matter content, grade, staple length, or nep count of the packaged cotton.

The dust level in the cardroom was not affected by use of the retriever. However, data indicated that cottons cleaned with three lint cleaners and retrieving and recycling would produce slightly lower dust levels in the cardroom than cottons cleaned with one or two lint cleaners without retrieving.

Generally, ring and open-end spinning data showed the same results, i.e., no significant effects. Fiber tests and spinning data indicated that no significant change in fiber length or strength or yarn appearance should be expected

from using the retrieving system. Although differences between the without- and with-recycling treatments were small and not significant for any of the spinning data, results indicated a weak trend toward slightly lower quality and performance of some factors with the retriever. In particular, during ring-spinning there was a slight increase in the number of neps and imperfections in the yarn and somewhat of an increase in ends down when processing the lower quality cotton.

At 1979 cotton prices, the practical value of fibers recovered from two lint cleaners would be about \$10 per bale or up to \$113 million per year for an annual crop production in the United States of about 11.3 million bales. The retrieving apparatus also allows using more lint cleaners at gins to reduce the foreign-matter content of the cotton, since most of the spinnable fibers that would be lost are recovered.

To obtain results at field gins comparable to those attained in these experiments, guidelines established in this publication for properly deploying the lint retriever under a wide range of conditions should be followed to maintain high spinning performance and quality in the cotton. From a quality standpoint, it is not practical to retrieve greater amounts of lint than were recovered in the experiments. Also, when recycling recovered fibers to the bale, processing the retrieved lint through the lint cleaners is a necessary requirement.

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